



NASA Langley Research Center  
Hampton, Virginia

National Transonic Facility **NTF**

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# **Model Preparation Area for High Reynolds Number Propulsion Airframe Integration Testing at the National Transonic Facility**

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High Reynolds Number Aerodynamics and Testing



# Outline



- Introduction and Problem Statements
  - Background
  - The National Transonic Facility (NTF) Operations
  - Challenges with powered semi-span testing in a transonic cryogenic environment
- Model Preparation Area (MPA) Requirements
  - Jet Exit (Nozzle Performance)
  - Semi-Span using Side Mounted Support System (SMSS)
    - Flow Thru Nacelles
    - Turbine Powered Simulator (TPS)
    - Ejectors
    - Open Rotors
- Layout of MPA-4
- Concluding Remarks



**AERIAL VIEW OF NTF COMPLEX**

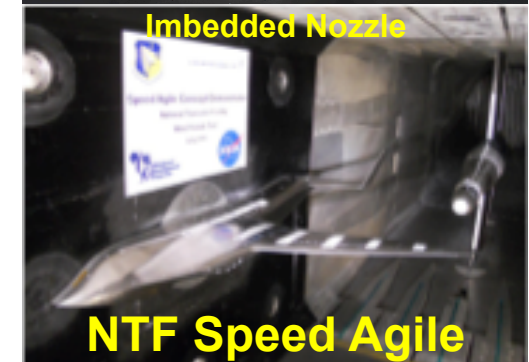




# Background – LaRC PAI facilities



- Examples of Propulsion Airframe Integration (PAI) facilities
  - LaRC 16-Foot Transonic Tunnel (Demolished)
  - LaRC Jet Exit (Demolished)
  - LaRC 14- by 22-Foot Subsonic Tunnel (14x22)
- High Reynolds number Propulsion Airframe Integration
  - NTF (Common Research Model)
  - NTF (Speed Agile – AFRL/LM)
  - NTF (HWB - AFRL/LM)
- High Reynolds number Active Flow Control (AFC)
  - NTF FAST-MAC  
(Fundamental Aerodynamic Subsonic Transonic - Modular Active Control)

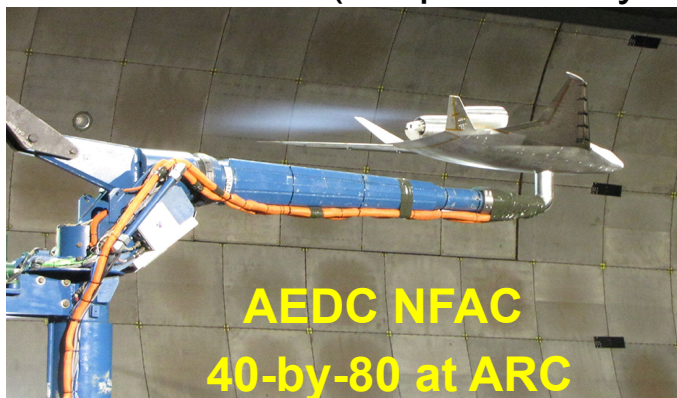




## Background - Other NASA PAI facilities



- NASA ARC Propulsion Airframe Integration
  - ARC Propulsion Simulator Calibration Lab (Demolished)
  - ARC Unitary Plan Wind Tunnel 11- by 11-foot Transonic Test Section (11-Foot TWT)
  - AEDC National Full-Scale Aerodynamics Complex (NFAC) 40-by-80 Foot Test Section (40-by-80)
- NASA GRC Propulsion Airframe Integration
  - GRC 9- by 15-Foot Low Speed Wind Tunnel (9x15 LSWT)
  - GRC (Propulsion System Laboratory)

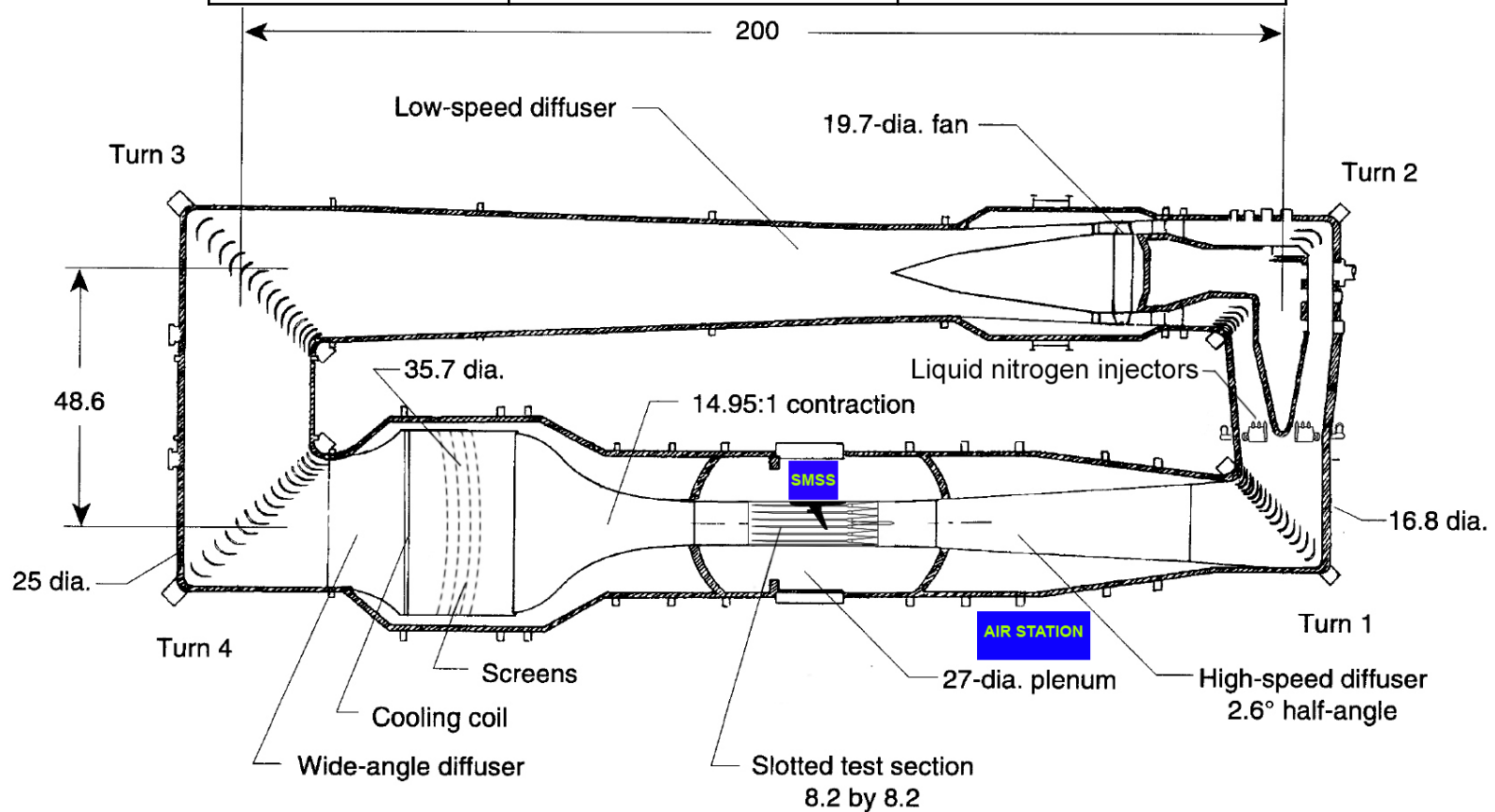




# National Transonic Facility – NTF



<b>Test Section</b>	8.2 x 8.2 x 25 Feet ( 2.5 x 2.5 x 7.6 meters)	
<b>Pressure</b>	14.7 to 133 psia; 1 to 9.0 atm.; 1.01 to 9.1 bar	
	<b>Air Operations</b>	<b>N<sub>2</sub> Operations</b>
<b>Mach No.</b>	<b>0.2 to 1.05</b>	<b>0.2 to 1.20</b>
<b>Reynolds No. Max</b>	<b>20x10<sup>6</sup> / ft (65x10<sup>6</sup> / m)</b>	<b>145x10<sup>6</sup> / ft (475x10<sup>6</sup> / m)</b>
<b>Temperature</b>	<b>90° to 150°F (32° to 65°C)</b>	<b>-50° to -250°F (-45° to -157°C)</b>



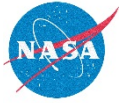


# NTF MPA 4 Requirements for Thrust Calibrations and Momentum Tares



- Dedicated facility (or location within existing facility) with necessary equipment/utilities
  - High-pressure air (1800/5000 psi and up to 30 lbm/sec delivery)
  - Temperature control (compensate for Joule Thompson effects)
  - Accurate and well-maintained mass flow measurement capability
  - Force measurements
- Ability to vary ambient pressure is desirable but may not be a firm requirement
- Staff should be available for calibrations and tares but won't be a full-time activity
  - Maintain continuity with staff assigned to this task to keep high level of expertise



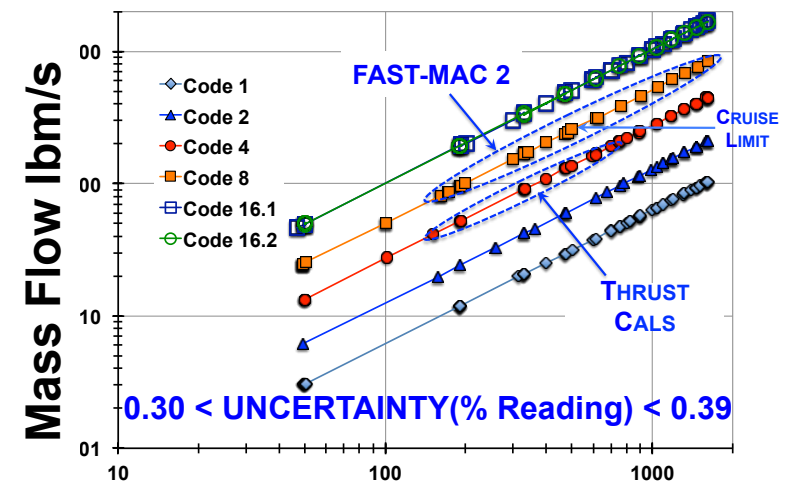


# Unique challenges with powered semi-span testing in a transonic cryogenic environment

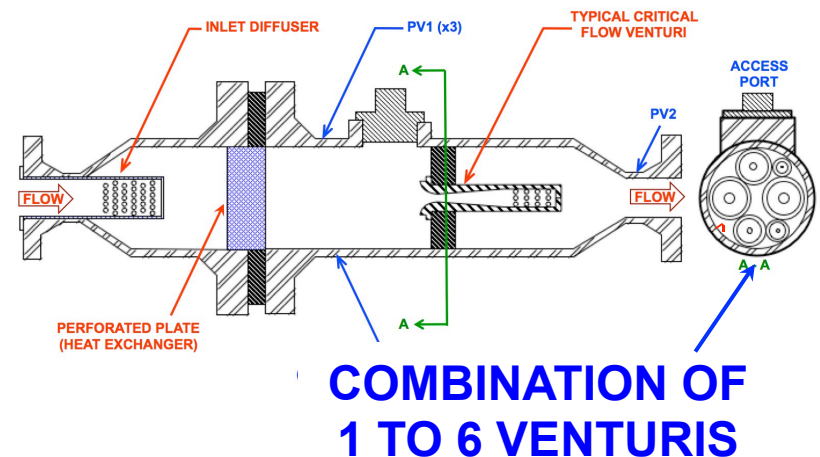


- Data repeatability is dependent on NTF 117 balance and Multiple Critical Venturi (MCV)
- Large dynamic pressure may require custom fan set for TPS and Open Rotor testing
- Operations vary with tunnel temperature
  - Cooling requires less power to operate motor
  - Cooling reduces fan tip speed
- Mechanical stability of motor system
  - Lubrication is challenging
- Safety
  - Risk associated with blade failure condition

## MCV Operating Envelope



## Inlet Pressure PSI

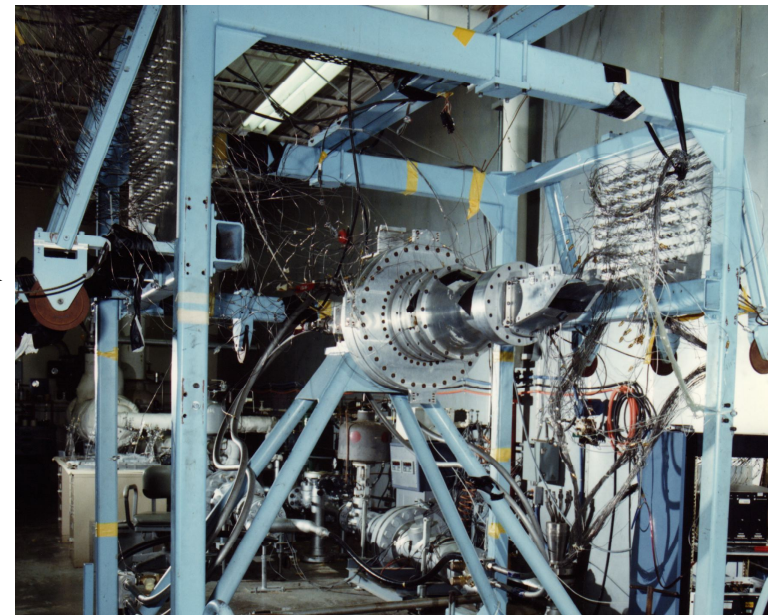
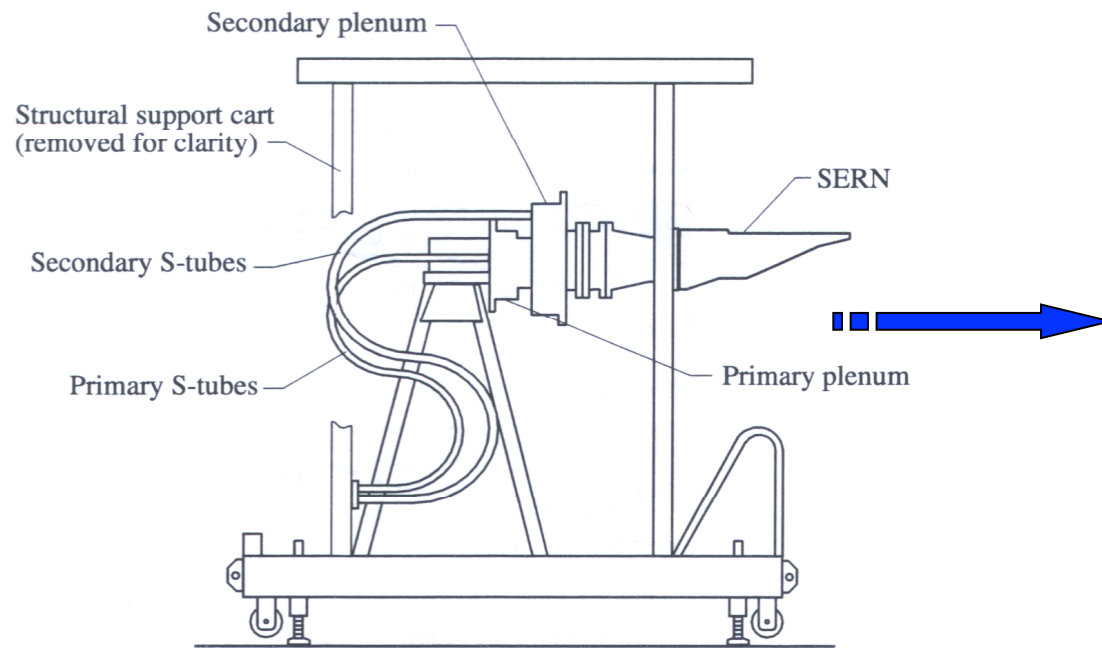




# Nozzle Testing



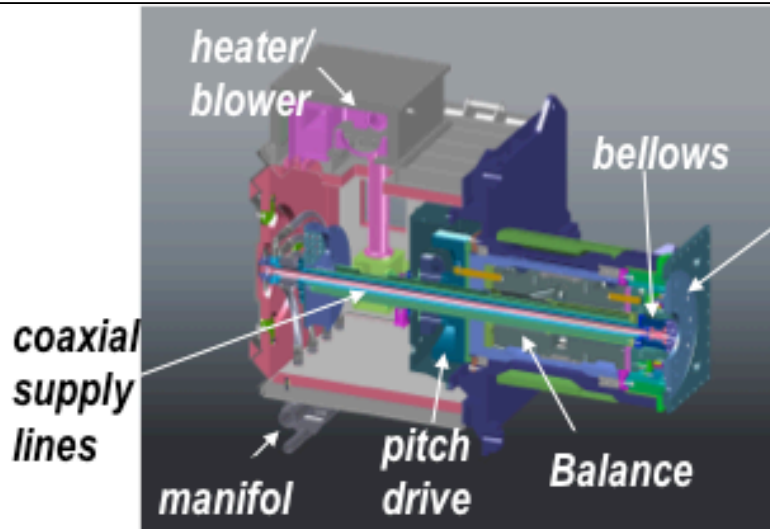
## Re-purpose LaRC Jet Exit test stand



## Dual Flow Test Stand/S-Tubes

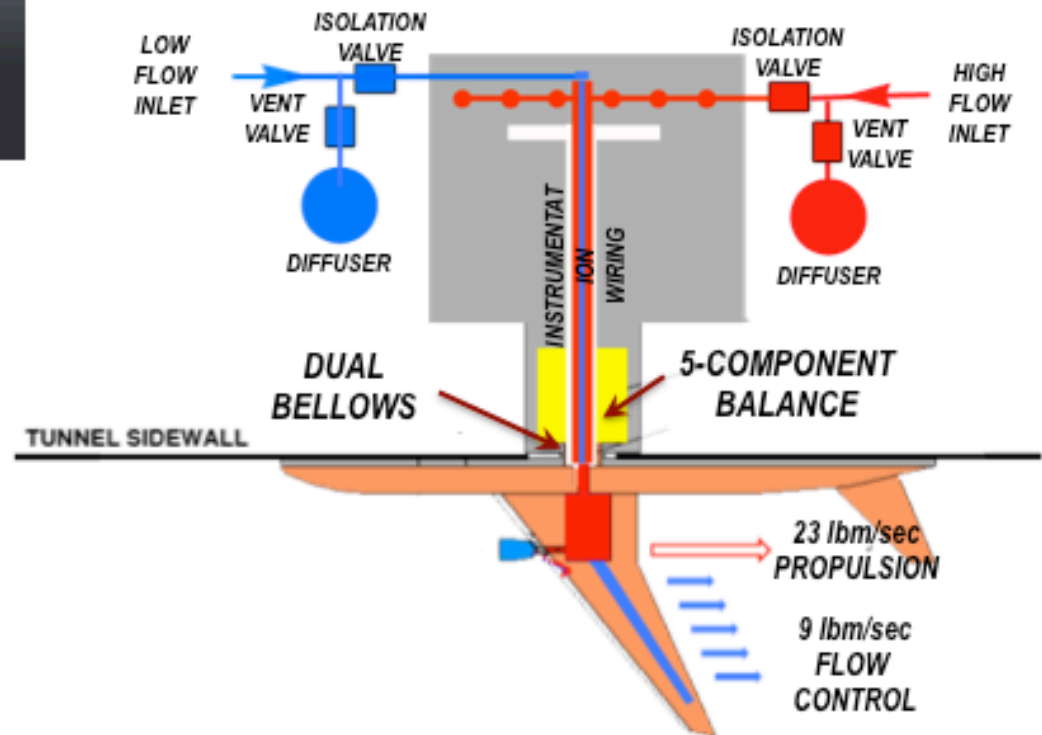


## SMSS (2 Independent flow paths)



model  
turntable

### SIDEWALL MODEL SUPPORT SYSTEM (SMSS)



The current temperature limit of  $-50^{\circ}\text{F}$  is based on the operational limits of the vent and isolation valves associated with the SMSS safety system

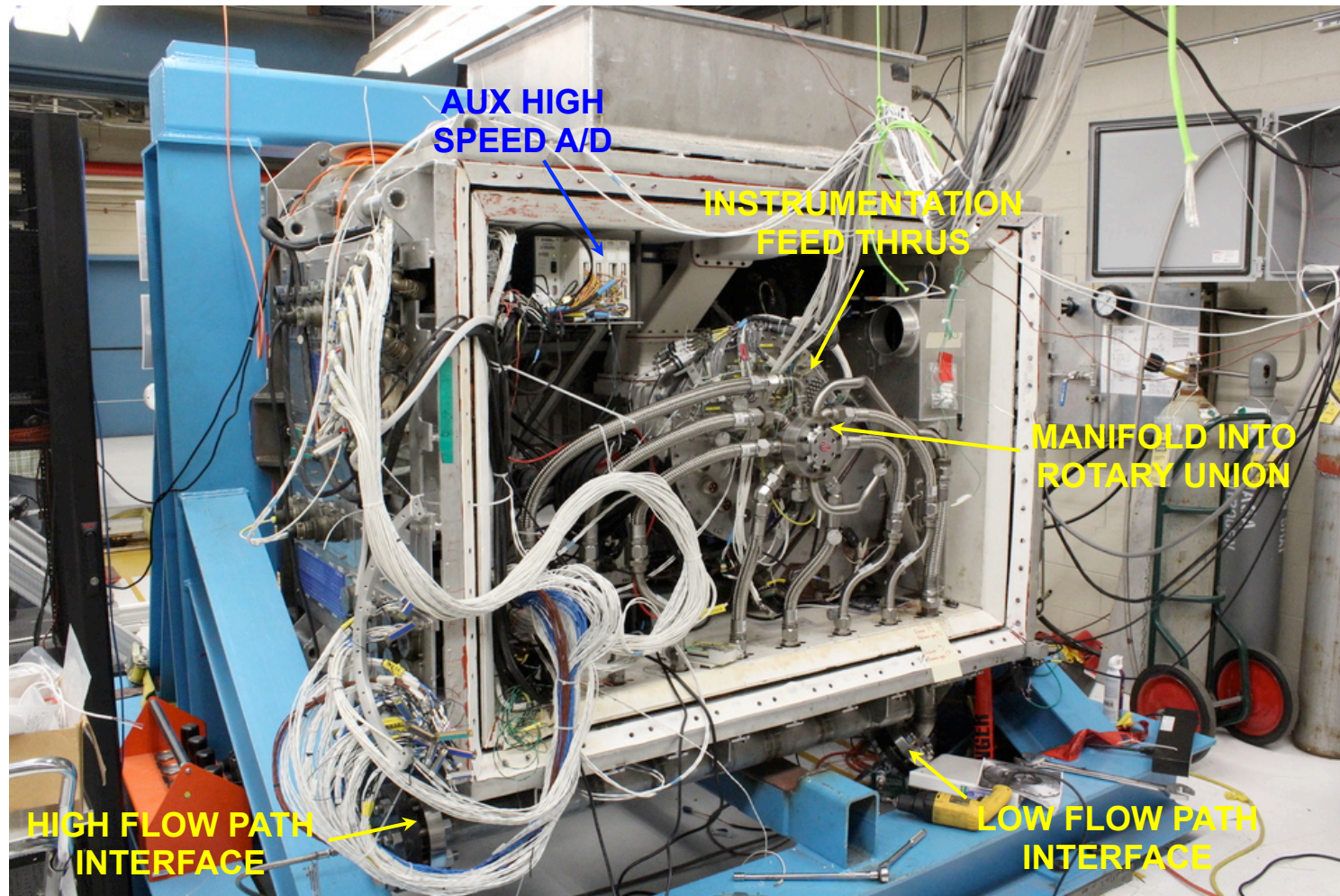




# MPA 1 (Instrumentation checks)



REAR VIEW OF SMSS w/ DOOR REMOVED  
BOX TEMPERATURE MAINTAINED AT 100 F



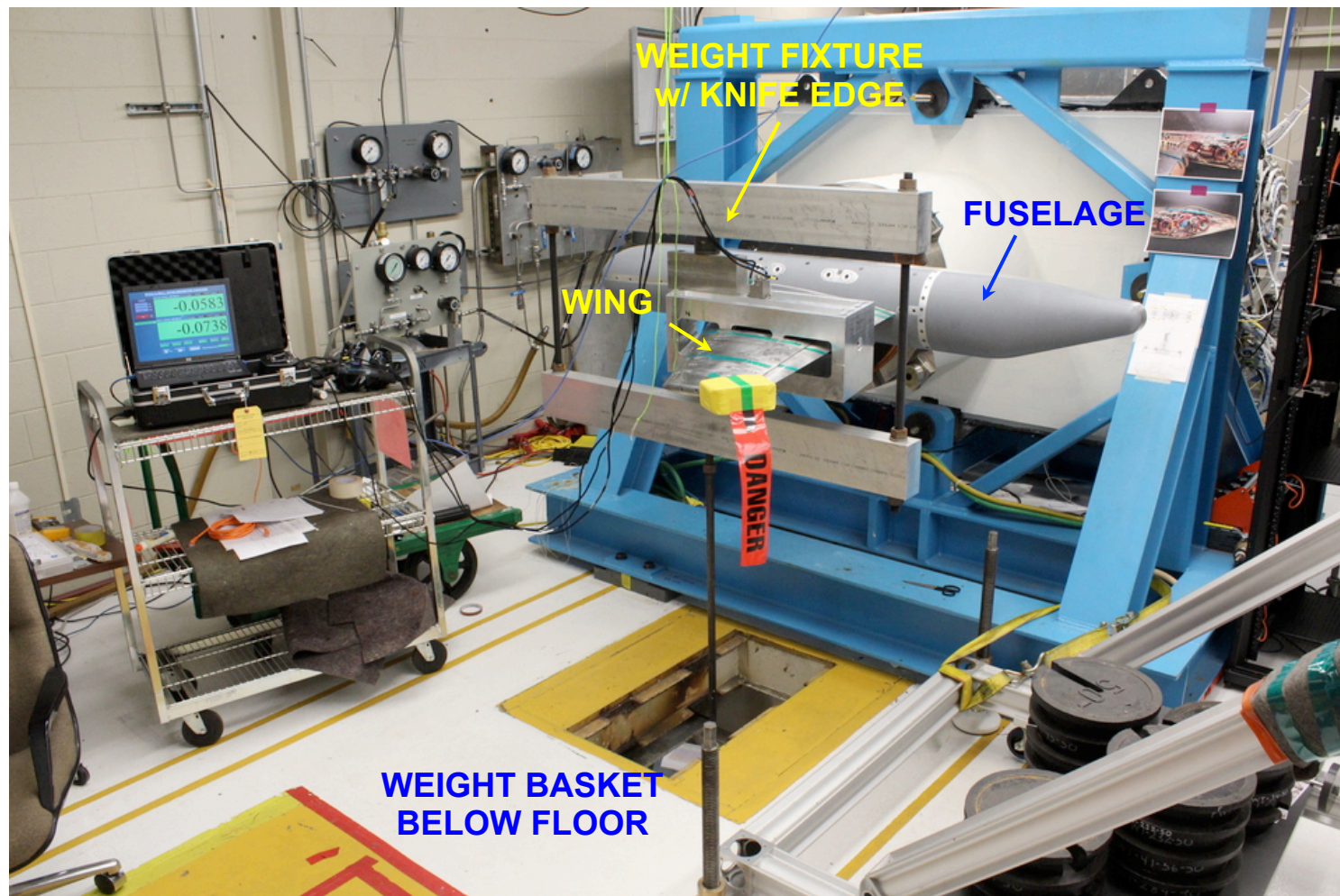




# MPA 1 (SMSS balance calibration configuration)



**NORMAL FORCE LOADING - EVALUATE FOULING (w/ PRESSURE INFLUENCES)  
ROTATED 0° (DOWN FORCE)**





# MPA 4 Safety



- High Noise environment
- Blade Failure for Open Rotor and TPS testing
- High Pressure system (1800 psig)
- High Flow systems (30 lbm/sec)
- Nozzle Pressure Ratio
  - (typical:  $1.0 < \text{NPR} < 6$ )
  - (max :  $1.0 < \text{NPR} < 25$ )
- Temperature Control (Steam Heat)







# TPS Calibration in Tunnel



- Specialty hardware
- Occupies tunnel (potentially interferes with other testing)
- Very costly even with reduced tunnel occupancy charges
- Does not check for fouling of final test configuration





# Recent Semi-Span Testing



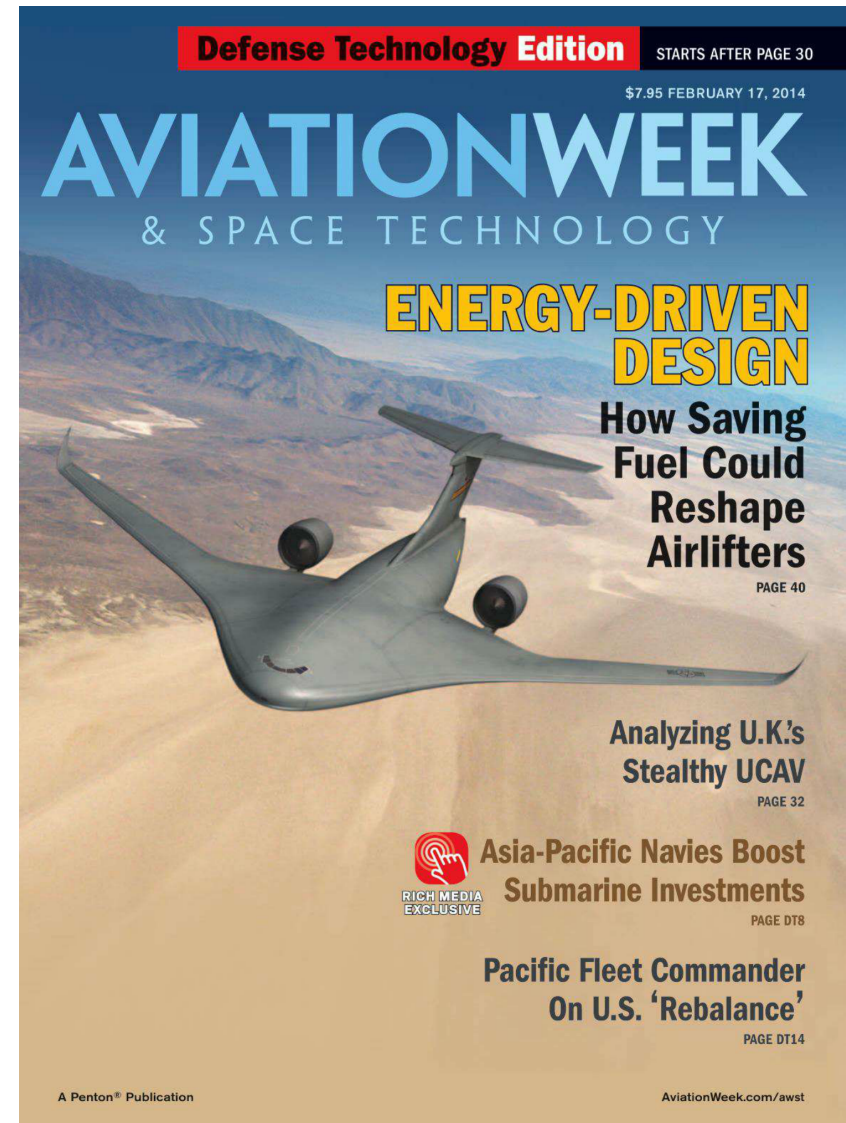
- Hybrid Wing Body with Flow Thru Nacelles
  - Improvements made to SMSS balance heating system
    - Resulted in a repeatability of 1 drag count for baseline
  - AFRL/LM Planning follow-on test
    - Evaluate Open Rotor Configuration)

## Collaborative Effort

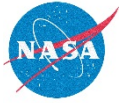


imagination at work

LOCKHEED MARTIN



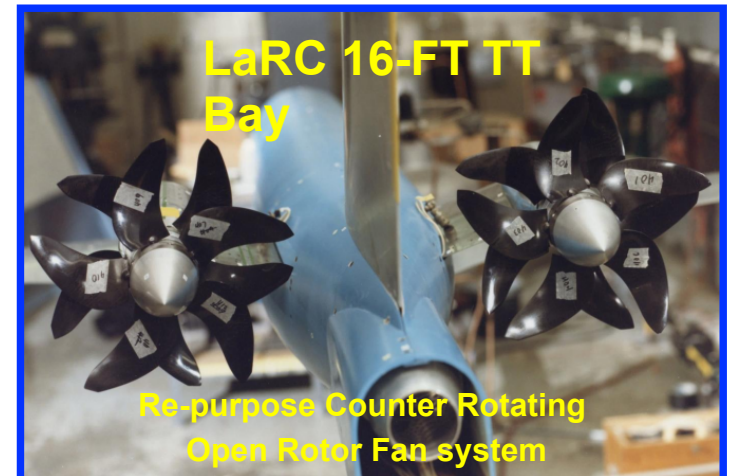
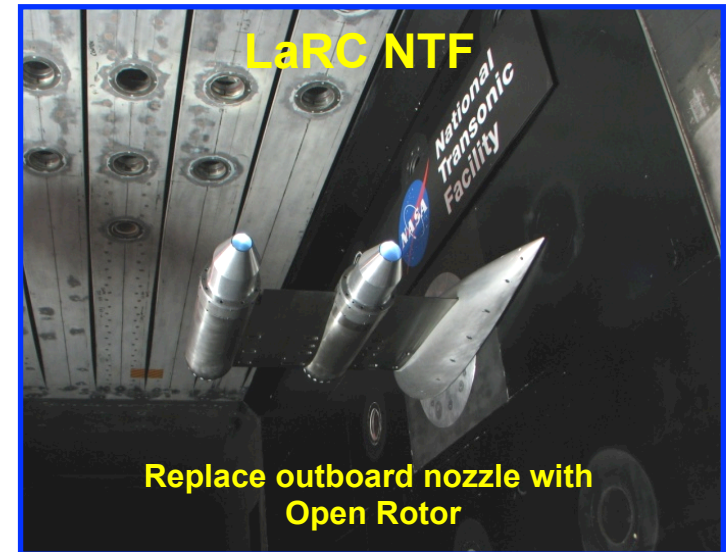




# Risk Reduction Semi-Span Open Rotor Testing



- Open rotor would be mounted to SMSS
  - Modified Dual Aerodynamic Nozzle model
  - Two independently controllable high pressure air lines (1275 psig)
    - High: 0.1 - 20.0 lbm/sec
    - Low: 0.1 - 8.0 lbm/sec
  - Equipped with calibrated Stratford nozzles
  - Air system (valves) limited to -50°F ops
- SMSS incorporates 5-component balance
  - Determine the risk to SMSS balance due to open rotor catastrophic failure





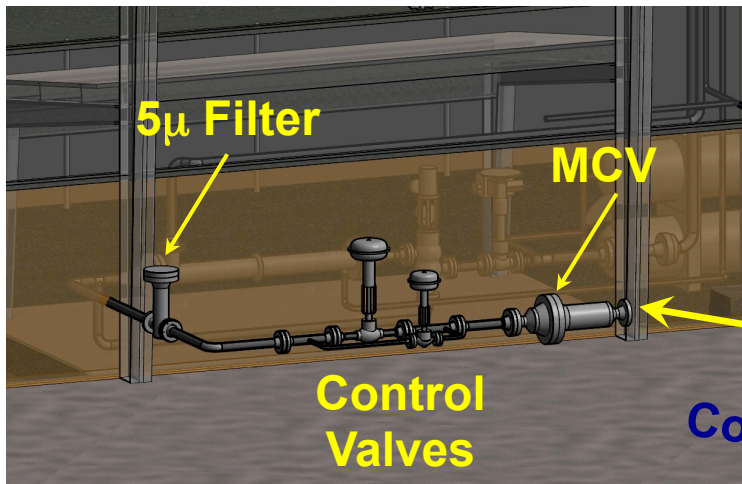
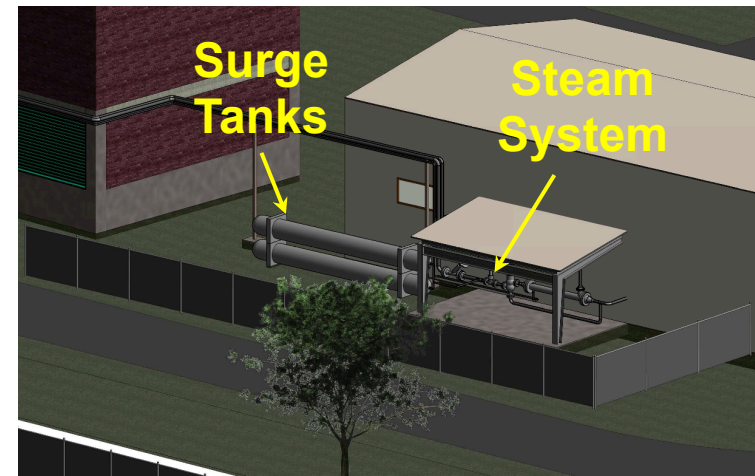
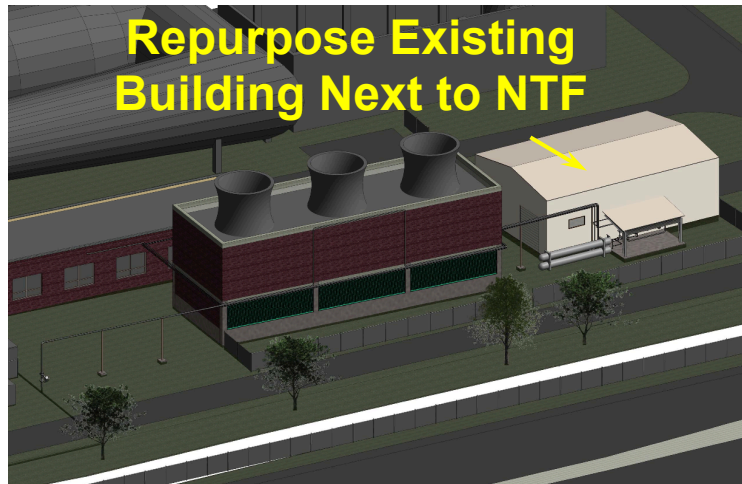
## MPA 4 located next to NTF Complex



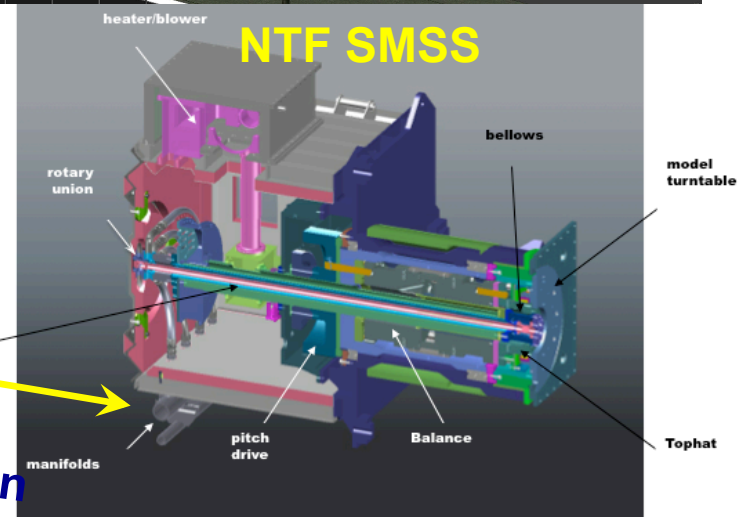




# NTF MPA 4 (Location is part of the NTF complex)



Hose Connection





# Concluding Remarks

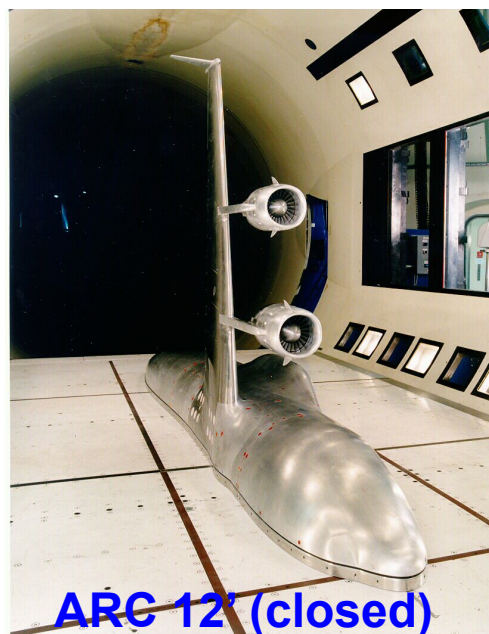
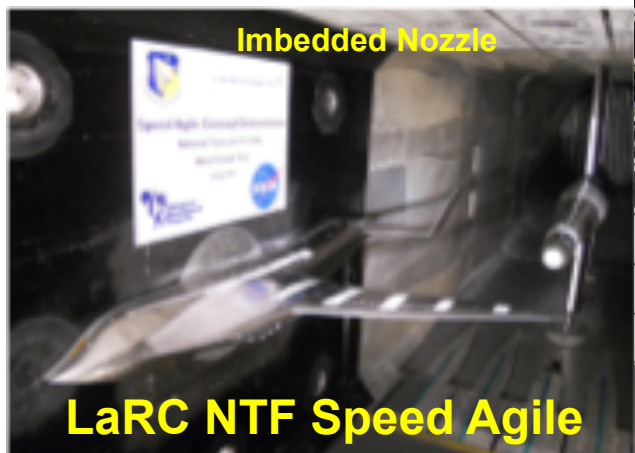


- Work with Industry, DOD, and University partners to develop a Model Preparation Area that supports high Reynolds number PAI testing
  - This supports the need to have a dedicated setup area for pretesting and calibration prior to entering the tunnel (avoiding costly calibrations in the test section)
- Develop high Reynolds number testing techniques for flow physics based research in active flow control and Propulsion Airframe Integration configurations
- Improve data accuracy and repeatability related to Propulsion Airframe Integration calibrations and momentum tares
- Evaluate different AFC techniques to improve aircraft performance with optimized Propulsion Airframe Integration





# Questions?





# BACKUP

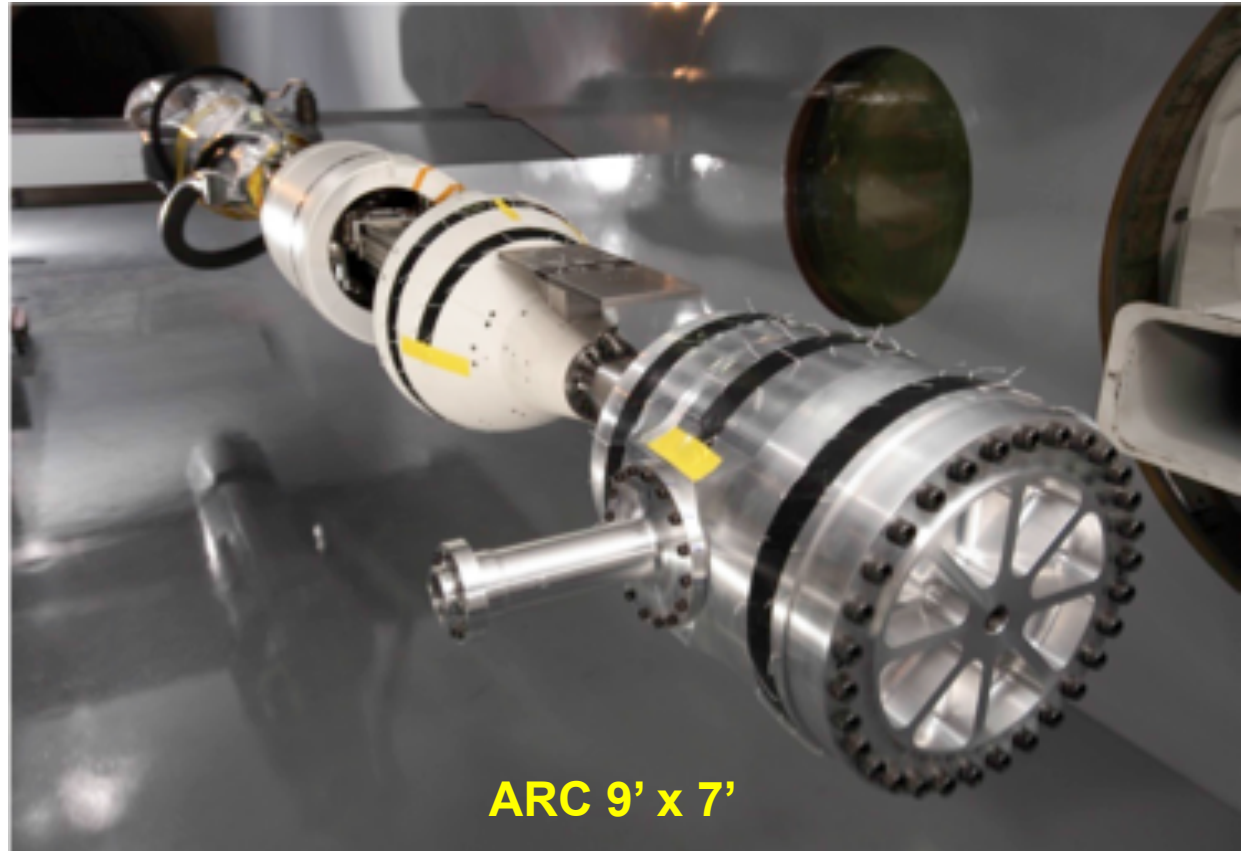




# Orion Ascent Abort Test Momentum Tares



- Custom setup in Ames 9x7 to perform momentum tares
- Costly occupancy (even at special rate negotiated for tares) and custom hardware required for test Section
- May not have been best internal flow path to establish momentum tares







# MPA 1 (SMSS balance calibration configuration)



AXIAL FORCE LOADING  
ROTATED 90° (THRUST)

